Groundwater Studies 2001/2002

Technical Terms of Reference

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Acknowledgments ...

This Technical Terms of Reference document reflects the many discussions and energetic dialogue that has occurred through and since 1997 with the inception of the Provincial Groundwater Management Studies under the Provincial Water Protection Fund.

In dealing with the difficult technical issues, the Grand River Conservation Authority, Regional Municipality of Halton, Conservation Ontario, the thirty-four groundwater studies teams and numerous technical consultants, Ontario Ministry of Natural Resources, Land Information Ontario, Ontario Geological Survey, Geological Survey of Canada, Toronto Region Conservation Authority, Ontario Ministry of Environment staff, Ontario Ministry of Agriculture and Rural Affairs, Ontario Ministry of Municipal Affairs and Housing continued to share their practical insight and professional practices.

Table of Contents ...

1.0 General Requirements for Groundwater Studies ...

This document outlines the technical terms of reference for the Groundwater Studies completed through Ontario's Operation Clean Water initiative announced August 22, 2001.

Groundwater Management Studies were first initiated in 1997 through the Provincial Water Protection Fund. Since that time, 34 groundwater studies involving some 100 municipalities and thirteen counties have been completed. The experience of those initial studies has been relied on to gather together the information provided in this document.

The purpose of this terms of reference is to define the requirements for consultants, municipalities, conservation authorities, and health units, who are undertaking groundwater studies under the provincially announced Groundwater Studies initiative 2001/2002. The information and analysis generated by these studies represents the first phase of groundwater source protection, will assist in developing future environmental policy, and will support the development of local and regional groundwater protection strategies.

The information presented here provides a general description of the objectives, and in particular, outlines the interim minimum standards, thresholds, and requirements to be used in carrying out the groundwater studies. Work is expected to continue on these interim standards and requirements in the future in order to meet the Groundwater Study objectives. The following are the general requirements for Groundwater Studies.

1.1 **Partnerships**

Because groundwater systems do not conform to municipal boundaries, municipalities, conservation authorities and other stakeholders need to work together on these groundwater studies. Cooperation among participants will enable the collection of compatible groundwater data that will extend to the natural boundaries of watersheds and groundwater aquifers.

Specifically, cooperation will be required among upper and lower-tier municipalities, public utilities, health units and conservation authorities in undertaking groundwater studies. Conservation authorities are capable of providing an essential watershed-level perspective to municipal groundwater studies, as well as a high degree of technical expertise. Accordingly, wherever feasible and with the agreement of all affected parties, it is expected that representatives from Conservation Authorities will play a major facilitating role in studies (e.g., project management). Upper-tier municipalities are also expected to play a leadership role in these studies, depending on local circumstances.

1.2 **Steering Committee, Public Involvement, and Project Management**

A steering committee is required for each study, and would be responsible for overseeing the technical and public involvement aspects of the study. It is strongly recommended that the steering committee include not only technical, municipal and consulting staff, but also representatives of the agricultural, environmental, business, and industrial sectors, as well as community groups that may be affected by future municipal groundwater strategies. At a minimum, the steering committee is expected to meet quarterly through the study process.

Involvement of the public in the study process is also an important part of groundwater management. If the members of the public are involved and informed in the early stages of a study which assesses the location of the resource, the risks of contamination, and current groundwater use, they are more knowledgeable and prepared to support implementation of appropriate protection and prevention measures.

Accordingly, each study must include a plan for informing and involving the public through a minimum of two, to three, public open house meetings, and other practical actions, such as setting up an education and information booth at community events. To assist with groundwater education, the Ministry of the Environment (MOE) will provide copies of a groundwater education video, entitled "*Groundwater: Our Hidden Treasure*" to all grant recipients.

Depending on the scope of the study, a project manager may be required.

1.3 Funding Information

Grant recipients will receive baseline funding to cover 70% of approved groundwater study costs with an increase to 85% for the inclusion of the following activities:

a) digitizing all data collected and submission of the data to the MOE,
b) georeferencing of all communal wells in the study area and submission of the georeferencing to the MOE, and
c) developing an action plan outlining next steps for groundwater source protection for the study area.

Note: Some key actions to consider in examining source protection and prevention options for groundwater communities include:

- *land securement and protection mechanisms;*
- *private land stewardship;*
- *wellhead and groundwater source protection policies;*
- *pollution prevention activities;*
- *community involvement, education, and outreach programs; and*
- *monitoring and contingency planning.*

1.4 Eligible Study Costs

1. Costs paid to professional specialists (e.g., hydrogeologists, engineers, economists, planners) and project management consultants for studies are eligible, provided the municipality ensures these costs are properly supported by invoices and related solely to the study project.

2. In-house labour costs are not eligible. The costs of contract, part-time, and student labour hired specifically for the project are eligible.

3. Miscellaneous costs related to the study as required by the consultant (such as rental of specialized equipment, drilling, pumping tests) are eligible. If in doubt, municipalities should consult with the MOE.

4. Financing costs, such as debenture costs and interest costs (interim financing charges), are not eligible.

2.0 Groundwater and Aquifer Characterization Studies ...

Local groundwater conditions should be understood within the context of the larger, regional groundwater flow systems of which they are a part. Basic groundwater functions of recharging, transmitting, attenuating potential contaminants, and storing and discharging water are necessary to provide a secure supply of clean water to communal water systems as well as individual groundwater users without access to a municipal supply. These regional groundwater functions also play an essential role in maintaining ecosystem health, including aquatic and terrestrial ecosystems.

Accordingly, an understanding of regional groundwater conditions and their inherent susceptibility to contamination, is critical to maintaining these ecological and sustainable use functions. The objectives are as follows:

a) to define the aquifer resources of a municipality and watershed through a series of maps and data sets meeting a minimum provincial standard;

b) to have consistent groundwater mapping at a scale of 1:50,000;

c) to conduct analysis with a clear methodology relating the data to the final product; and

d) to use at all times the best possible information available.

2.1 Local and Regional Groundwater Conditions

Purpose – In order to bring together data and information that is used for the long term management of groundwater resources, such as wellhead protection, aquifer management, water supply and demand planning, water budget maintenance, and integrated watershed planning, the studies should be designed to provide a good understanding of both regional and local groundwater conditions.

Conceptual Model – The first step in developing this understanding is to create a conceptual model of the groundwater system in the geographic area being studied. This means assessing the features and functions of the groundwater resources, and cataloguing stresses and threats, such as water takings, effluent discharges and contaminant sources. A thorough understanding of the data and information gaps will have implications to the comprehensiveness of the plans. Separately, but also important is determining the barriers to source protection created by the fragmentation of the regional groundwater systems as result of institutional and municipal boundaries.

The integration of a diversity of data and information for a clearer understanding of the dominant elements of the groundwater flow system within a study area includes the geologic processes, the geochemical processes, changes in the landscape and the effects on the character, distribution, hydraulics and flow of water through the system. Ultimately, the conceptual model can be described in terms of critical features and functions of the hydrogeology, including flow paths, times of travel, confining layers, unconfined layers, semi-confining layers, aquifer characteristics, recharge areas, and discharge areas. Geochemistry and existing contamination will be invaluable to developing the conceptual model.

Although the key objective of a preliminary data analysis is to form a conceptual geological and hydrogeological model for interpreting water occurrence, character, and movement, as much hydrogeological information (pump tests, contaminant studies, monitoring data, etc.) as feasible should be reviewed and assessed in developing the conceptual model. A preliminary data analysis will yield a general understanding of the data distribution and density within a study area. Through this process, data validation becomes possible.

Data Gaps – The ideal is to use all of the data giving regard to the provenance including anecdotal information such as spot measurements and recollections, by assigning relative importance to the individual data points and components. Where data is absent on any portion within the sequence or having a poor spatial distribution across the study area this must be noted early within the study process. These identified data gaps can be used to plan for and obtain necessary data through the study process.

In some cases, data gaps can be seen and thereby potentially guide the process for the collection of further relevant data. This step allows the clear transition from raw data to the more complex data analysis processes possible through the use of geostatistical, relational database, and GIS mapping tools.

Data Validation – The validation process for bringing together the best and most reliable data within a given study area may be time consuming, however, without a documented validation process to define the data set used in preparing derived map products, the results are likely suspect. Data validation processes must select for the data that best represents the entire groundwater active sequence in a study area in overburden as well as bedrock. See details on standardization objectives, methods and rules presented in *Schedules A* through *G* later in this document. Data selection and validation rules, when used, must be stated and included in the metadata. The following are typical data validation processes:

- *Location* **–** checking congruity between various data sets such as geographic references such as county, township, lot and concession, physical features, air photos, parcel fabric, digital elevation model, historical topographic maps used to estimate map-based co-ordinates, use of GPS measured georeferenced co-ordinates , use of existing reliability coding, matching well owner names, etc;

- *Elevation* **–** checking congruity between water well elevation with historical topographic maps, the provincial digital elevation model (DEM), benchmarks, geodetic survey information, use of GPS, use of elevations on water bodies such as streams, reservoirs, lake and wetlands that preserves the direction and descent of surface flow representing the establishment of drainage areas such as watershed and subwatershed, recognizing closed drainage areas such as hummocky terrain and karstic areas;

- *Interpretation* **–** checking congruity, confirmation and evaluating the balance of evidence using geophysics analysis, sample results, core analysis, outcrops, geotechnical boreholes as well as oil and gas boreholes to corroborate a sequence of geological environments of deposition/erosion and corresponding paleoecological environments, identifying hydrogeological settings and active hydrogeological units such as aquitards and aquifers, corresponding water quality, age, and major flowpaths accounting for both transient and steady-state conditions for both horizontal and vertical movement. There has been consensus about applying the GSC geomaterial protocols early in the borehole geology data interpretation; and

- *Metadata* **–** The provincial metadata standard available through MNR Land Information Ontario is to be used for the groundwater studies. Each of the data and map products will be registered as a record and details regarding data validation will be entered in the areas entitled “Data Sources” or as appropriate in other sections. See *Schedule B* in particular for an example for documenting the metadata related to the GSC Geomaterial Protocol.

2.2 Methodology for Defining Groundwater Intrinsic Susceptibility

Purpose – In general, groundwater intrinsic susceptibility maps identify areas where contamination of groundwater is more (or less) likely to occur as a result of surface contamination. It is anticipated that land managers, municipal planners, and facility owners and operators will be able to use groundwater intrinsic

susceptibility (GwIS) maps showing the areas of high, medium, and low intrinsic susceptibility and index values at point locations. The GwIS maps can be used as a general guide to preserve existing groundwater resources by diverting potentially harmful land use from areas of higher groundwater susceptibility to areas of lower groundwater susceptibility. Furthermore, recognizing that today's groundwater contamination is tomorrow's surface water contamination, the maps can be effective in preserving the ecosystem functions linked to the groundwater systems.

Rationale – The rationale for this method is linked to time of travel. The vulnerability is tied to arrival of a contaminant at the water table and or the shallowest aquifer. The method is not geared to assessing a specific contaminant, contaminant group or human activity. This method assesses intrinsic vulnerability or susceptibility with limited consideration of the specific attributes of the hydrogeologic system or the behavior of contaminants. The two key attributes considered are the depth to water table and the conductivity of geologic material in the unsaturated zone (or above a confined aquifer). Although the method considers only the intrinsic susceptibility of the shallowest aquifer, deeper aquifers will be of interest to the local municipality. A modification of this method that uses an "effective thickness" instead of depth to water table, where the effective thickness represents the time of travel to the aquifer, would be a useful first cut at determining the intrinsic susceptibility of aquifers below the shallowest aquifer. This method is also used for determining the intrinsic susceptibility of confined shallow aquifers. Here, the depth to the aquifer is used instead of the depth to water table.

Intrinsically, fine unfractured media retards contaminant migration whereas fractured media, or coarse porous media, provides faster travel times and less retardation and hence more vulnerability. For example 20 metres of silt over a confined aquifer would have a low intrinsic susceptibility. But 10 metres of clean coarse sand or fractured rock would have a high susceptibility to contamination.

There are other factors that could be used to improve the understanding of a system's intrinsic susceptibility to contamination. Such factors may include gradients, recharge and discharge, flow paths and local geology. This information can be used to adjust the intrinsic susceptibility values.

This method presumes sufficient water well records and topography information are available to predict water table with certainty over the geographic area. In some areas, insufficient water wells, lack of a digital elevation model, or other issues may preclude the use of water table. In these cases, an "effective thickness" may have to be used that best approximates depth to water table.

Goal – Mapping of groundwater susceptibility should be undertaken using the MOE Water Well Information System (WWIS) as a primary data source. Vulnerability mapping is a tool that can be used to make planning decisions to protect groundwater resources and its ultimate use.

A key product is mapping of the groundwater intrinsic susceptibility to contamination at different levels of susceptibility (e.g., low, medium and high.) The mapping requires a careful assessment of the groundwater system and then moving to identify critical factors that can be used in the mapping of vulnerability. Decisions about additional factors and their application going beyond the method described here rest with the groundwater expert and the local study teams, in consideration of the needs of the product users. The MOE requires that the following methodologies be used as a minimum standard.

General Procedures – The hydrogeologist must develop a conceptual model of the hydrogeologic system for which the intrinsic susceptibility mapping is to be created. Developing a hydrogeologic conceptual model will require the expertise of an experienced hydrogeologist. The hydrogeologist can then determine the critical factors that must be assessed and integrated into the susceptibility assessment.

In the context of the data available from the MOE Water Well Information System (WWIS), groundwater intrinsic susceptibility can be inferred from the well geology, water table position, vertical gradients and possibly the screen location. The method prescribed herein will focus on the geology and water levels alone. Screen locations are considered to be often more reflective of a deeper 'production aquifer', rather

then a surficial aquifer with important ecosystem functions. Screen locations are therefore not used in the methodology, but may be considered for any additional maps assessing the deeper aquifers.

The method is based on calculating a susceptibility index at each well, then mapping the indexes using an interpolation technique such as kriging (although even hand contouring may be effective in some areas). Both the map and the individual well indexes are deliverables of this project. The index calculation requires a sequence of logical statements to evaluate the hydrogeological conditions at each well, followed by arithmetic statements to sum up the net susceptibility index at each well. This is achieved conveniently using a programming language such as VB or VBA within a database such as Microsoft Access (although it may also be accomplished with spreadsheet software). Several of the steps will also require a working knowledge of GIS software with interpolation packages. For details, refer to *Schedule A: Required Groundwater and Aquifer Characterization Components with Methodologies*.

Uncertainty – In light of the general uncertainty within the data in the WWIS, it is strongly recommended that the groundwater intrinsic susceptibility (GwIS) maps not be used directly for planning purposes without further site specific verification regarding any potential sources of contamination.

Local Expertise – Consultants are encouraged to apply local expertise to improve the quality of the mapping product. The Ministry recognizes that elements of the maps, such as water table, are the product of considerable interpretation. Local knowledge of groundwater flow systems, pump tests, geochemistry, soils, topography and other factors could have important effects on vulnerability assessments when taken into account. For the local context the consultant must apply knowledge of local hydrogeologic/geologic conditions, factors and uncertainties in existing databases to enable the best decisions to be made on vulnerability. Only limited procedures are offered in applying decisions in these cases.

Study participants are also encouraged to apply local hydrogeological knowledge and expertise to develop enhanced local scale Groundwater Intrinsic Susceptibility (GwIS) maps for immediate land use planning applications. The mapping procedures are left to the discretion of the funding recipient, but should include locally relevant hydrogeological data and an appreciation for local groundwater flow systems.

References – The International Association of Hydrogeologists publication “Guidebook on Mapping Groundwater Vulnerability” (1994, edited by Jaroslav Vrba and Alexander Zaporozec) is recommended as useful reference to further understand founding concepts of aquifer vulnerability mapping, and provide guidance on the use and interpretation of the data types available.

2.2.1 <u>Step 1: Data Preparation</u>

Geological Descriptions – The Geological Survey of Canada has developed rules for improving the geological descriptions in the MOE Well Log Database which are presented in *Schedule B*. These revised descriptions will be included in the database provided by the MOE or otherwise made available to grant recipients, and should be used for the GwIS map. A list of the GSC terms is included in *Schedule B* of this document. This step has been shown to improve the quality of the geological descriptions used for the GwIS map.

Well Selection and Screening – All wells with a MOE Well Log database universal transverse mercator (UTM) or Elevation Reliability Code error of more than 6 should be initially filtered out of the analysis. The UTM error code refers to the estimated accuracy of the UTM coordinates for the well; a code of 6 implies an error of at least 300 m. Similarly an Elevation Error Code of 6 implies an elevation error of at least 15 metres.

2.2.2 Step 2: Water Table

A depth to water table map is a requirement of the groundwater study, and is to be used in the preparation of the GwIS map. The water table depth map should be prepared by interpolating a water table surface based on the static water level depths from shallow wells. The consultant is required to assess the local hydrogeological regime and develop a rationale for selecting 'shallow wells' and other relevant data points for the generation of a water table map. The map will be considered the 'best available' depth to water table surface, and should be updated periodically as new information comes available.

Database Updates – The depth to water table is required at all wells in order to calculate the groundwater Intrinsic Susceptibility Index (ISI) at each well. The consultant is therefore required to add the interpolated depth to water table from the map to all wells in the database for the study area.

Inadequate Or Unreliable Water Table Data – For each stratigraphic layer, for selected "Effective Thickness" or depth from ground surface, which has been derived from the preliminary data analysis, a K-Factor (see *Schedule C: Generic Representative Permeability (K-Factor*) Table) is estimated and is multiplied by the thickness of that layer. The summed value of the K-Factors is then used to classify whether an area is of High, Medium, or Low Intrinsic Susceptibility to Contamination. This method can be used where it can be justified to the MOE, prior to using the method, that the water table information is inadequate and will lead to misleading or unacceptable uncertainty. The rationale will need to be provided to the MOE, as well as the detailed description of the method. The MOE will decide what areas or parts of areas can be mapped using an alternate method. The "effective thickness" should represent a reasonable surrogate for depth to water table and/or depth to aquifer and should based on a review of all hydrogeologic information, including the water wells. Histograms of water wells with depth to water table, etc. should be included in the rationale.

2.2.3 Step 3: Calculation of Intrinsic Susceptibility Index (ISI) at Each Well

The preparation of the GwIS map includes calculation of an intrinsic susceptibility index (ISI) for each well. This value is written to the database and used to prepare the final map.

The ISI is calculated by summing the product of the thickness of each unit in the well log and a corresponding K-Factor. The K-Factor (reference table provided in *Schedule C*) is a dimensionless, relative number that can be loosely related to the exponent of the vertical hydraulic conductivity in m/s. The calculation is performed from surface to a lower limit defined by the water table configuration.

The consultant shall assess the geology at each well, distinguishing aquifers from aquitards to properly account for consecutive layers of similar materials.

The consultant shall determine on a well-by-well basis if the aquifer of interest is confined, semi-confined or unconfined. The regional groundwater intrinsic susceptibility (GwIS) map is focused on evaluating the uppermost 'significant' aquifer (to be determined by the consultant and the local study team), and considering:

- the use of the aquifer as a drinking water source;
- the linkage of the uppermost aquifer to any local surface water systems and the sensitivity of these systems; and
- the linkage the aquifer might have to deeper aquifers that are used for drinking water.

Confined Aquifers – For confined aquifers, it is reasonable to assume that contaminants from the surface must migrate through the confining layer and reach the aquifer to cause potential impact. Therefore, the ISI is calculated by summing the product of the thickness of each geological unit in the well and the corresponding K-Factor (refer to *Schedule C*), from ground surface to the top of the first significant aquifer.

Unconfined Aquifers – For unconfined aquifers, it is reasonable to assume that contaminants from the surface must only migrate to the water table to cause potential impact. Therefore, the ISI is calculated by summing the product of the thickness of each geological unit in the well and the corresponding K-Factor, from ground surface to the water table.

Semi-confined Aquifers – For semi-confined aquifers or where there is doubt about the integrity of the confining layer, it is reasonable to assume that contaminants from surface must migrate through a leaky layer and reach the aquifer to cause potential impact. Expert judgement is needed to evaluate the hydrogeological and hydrological information collected for the groundwater studies. Determining if a field of wells should have a modified K-Factor should be based on best professional judgement. The ISI is calculated by summing the product of the thickness of each geological unit in the well and an appropriate K-Factor (refer to *Schedule C*), from ground surface to the top of the water table.

Missing Aquifers – For wells where no aquifer material is detected, based on the codes provided in *Schedule B*, the ISI will be calculated as the sum of the product of the unit thickness and the K-Factor from the ground surface to 15 metres below the ground surface.

Data Reliability Issues – Where the data and well density are too low to confidently produce the mapping of the water table and geologic materials an alternate method must be proposed which is as faithful as possible to the MOE suggested method. Unreliable wells can be screened out.

Adjustments might also be appropriate where it is clear that certain information sources consistently misrepresent a geological feature of significance. The methods used must be clearly documented for dealing with data reliability issues and interpolation methods between water wells. Adjustments may be used as they arise during the derivation of enhanced local groundwater intrinsic susceptibility maps through the use of local expertise.

Definitions – The specific definitions of the first “significant” aquifer and what qualifies as a semi-confined aquifer, confined aquifer will be defined by the consultant in the context of local hydrogeological conditions.

2.2.4 Step 4: Categorizing Intrinsic Susceptibility Index (ISI) Values

For final mapping purposes, the ISI value at each well is categorized into Low (<30), Medium (30 to 80), and High (>80) groupings. The thresholds defining the limits of these categories will be established by the consultant to best reflect local hydrogeological resources and functions.

Once the initial classification has been applied and shown on a preliminary map, the classification limits may be adjusted to reflect local conditions by the consultant to produce the final derived map. The threshold rationale must be clearly described and justified, and account not only for water supply aquifers, but also the ecosystem functions as related to wetlands, rivers, etc..

2.2.5 Step 5: Mapping

The final map is developed by interpolating the categorized ISI values at each well. Although the selection of an interpolation method shall be at the discretion of the consultant, a kriging algorithm is recommended, using a grid cell size of 500m or less with a preference for a lower grid spacing.

Boundary Harmonization – Consultants must identify how boundary issues with adjoining municipalities will be harmonized. Adjacent study areas must work together for the harmonization of the thresholds where they have been modified from the original classification. Harmonization issues include: geomaterial coding, water table and confined or unconfined aquifer definitions, and intrinsic susceptibility evaluations. The MOE may provide ground rules on harmonization where there are circumstances of unresolvable harmonization of threshold tiers.

Intrinsic Susceptibility Thresholds –

- Low intrinsic susceptibility values will be greater that 80;
- Low to moderate intrinsic susceptibility values will be between 30 and 80; and
- High intrinsic susceptibility values will be less than 30.

2.3 Regional Contaminant Source Inventory

Another essential element in the protection and management of groundwater resources is an inventory of potential contaminant sources to the regional groundwater system. The purpose of this contaminant inventory is to identify past, present, and future (proposed) activities that could pose a potential long term risk to groundwater aquifers. A regional contaminant source inventory (CSI) will provide information on the location of contaminant threats and identify where future risk mitigation measures may be required.

Note: In some cases, a more detailed assessment of potential contaminant sources may be conducted in significant groundwater areas within the study area, such as groundwater recharge areas or areas that are intrinsically susceptible to contamination. If a more detailed assessment is undertaken, the consultant should follow the procedures described in Section 3.3 of this document – "Methodology for WHPA Contaminant Source Assessment".

2.3.1 Contaminant Sources Information Requirements

Information items to consider when conducting the regional contaminant source inventory (CSI):

- ❑ all known sources of contamination;
- ❑ all potential sources of contamination;
- ❑ potentially contaminated sites;
- ❑ high risk activities within or near recharge areas, including bio-solids application sites, garages, salt storage, and sewage treatment facilities;
- ❑ existing monitoring programs;
- ❑ probability of contamination associated with specific land uses; and
- ❑ potentially affected groups or individuals.

Refer to *Schedule D* for a list of common point and non-point potential contaminant sources along with their corresponding North American Industry Classification System (NAICS) codes. Regional contaminant sources must be catalogued using this numbering system.

2.3.2 Minimum Data Source Requirements

At a minimum, the regional CSI should document the location of potential sources from the following existing inventories:

- ❑ MOE Waste Generator database;
- ❑ MOE PCB Database;
- ❑ MOE Waste Disposal Site Inventory;
- ❑ MOE Municipal Coal Gasification Plant Site Inventory;
- ❑ MOE Certificate of Approval (CofA) databases (e.g., soil conditioning sites, landfills);
- ❑ Ministry of Natural Resources Petroleum Well records;
- ❑ Technical Standards and Safety Authority inventory of Underground Storage Tanks (UST); and
- ❑ municipal Official Plans and Land Use Schedules.

2.4 Methodology for Groundwater Use Assessment

This assessment will estimate the degree, purpose, and distribution of groundwater use in the watersheds within a study area to provide an overview of existing pressures on the quantity of local groundwater resources. By estimating current groundwater use, the study will contribute to a future water budget study for the area. A future water budget study would investigate factors influencing the availability of groundwater in the watershed (e.g., water inputs, water losses) and existing and future demands for water supply. Such insight would help water managers to forecast potential water supply shortages and determine what measures are required to maintain groundwater recharge, conserve existing supplies and sustain ecological functions in the watersheds.

2.4.1 Categories of Water Use

Within a given region, a diverse collection of users place demands on the water system. To facilitate the collection and sharing of data it is beneficial to classify water use into standard categories. Seven categories have been established and should be applied in the groundwater study. “Self supply” means water not obtained from a public supply. When possible, include the appropriate North American Industry Classification System (NAICS) codes to describe activities such as prescribed in Schedule D: Catalogue of Suggested Potential Contaminant Sources.

Public Supply	Water withdrawn for all uses by public and private water suppliers and delivered to users that do not supply their own water. Sub-categories of public supply include *residential*, *commercial*, *industrial, institutional,* and *public water use*.
Self Supply, Domestic	Domestic encompasses residential, commercial, and institutional uses. This category also includes water used for mobile homes, hospitals, schools, fire services, air conditioning and other similar uses not covered under a public supply. In addition, amusement and recreational water uses such as snow making and water slides should be included.
Self Supply, Irrigation	Water artificially applied on lands to assist in the growing of crops and pastures or in the maintenance of recreational lands, such as parks and golf courses.
Self Supply, Livestock	Water used by horses, cattle, sheep, goats, hogs, poultry, and other commercially important animals. Water used in fish hatchery operation is also included under this category.

Self Supply, Industrial (manufacturing)	Water used in the manufacturing of metals, chemicals, paper, and allied products.
Self Supply, Industrial (mining)	Water used in the extraction or washing of minerals. For example, solids, such as coal and ores, and fluids such as crude petroleum and natural gas.
Self Supply, Other	Water used for purposes not reported in previous categories.

2.4.2 Suggested Methodology

The cumulative estimate of water use in the study area watershed should be based, at a minimum, on information gathered from major sources, such as: public works and Public Utility Commission records, the MOE Permit to Take Water database, the MOE Water Well Information System, and Certificates of Approval. The suggested use and specific information requirements for these sources are described below. The use of additional sources of information to improve the accuracy of the groundwater use estimates (e.g., other databases, literature review, field survey) is encouraged, and must be documented.

Note: All flow volumes should be recorded in cubic metres or megalitres (ML - millions of litres) per unit time (i.e. cubic metres/month; cubic metres/day).

Public water supplier records – Data on existing uses and outputs in public supply systems should be obtained from the records of local *Public Utility Commissions* and *municipal public works departments*. From water supplier records, the following information is required:

- Water Works number, Certificate of Approval number
- Permit to Take Water number,
- design capacity and permitted capacity
- population served,
- average daily flow (by month), and
- total raw water flow (by month and year).

When available, the following information should also be provided:

- water use by sector (i.e., % domestic, % commercial, % industrial, etc.),
- verification of well and plant Universal Transverse Mercator coordinates (UTMs) or Geographic Positioning System (GPS) reference,
- daily per capita use,
- days when water supply did not meet demand,
- total monthly and yearly flows,
- maximum daily flow (by month),
- minimum daily flow (by month),
- raw water flow, and
- treated water flow.

PTTW database – The MOE *Permit to Take Water (PTTW)* database should be used to inventory uses and estimate water output by permitted large scale users (i.e., > 50,000 litres/day) in areas not serviced by public supply. Groundwater output estimates should be categorized by sector (i.e., self supply domestic, self supply irrigation, self supply industrial, etc.). In addition to obtaining information from the PTTW database, actual water use (not just permitted maximums) should be collected by identifying the large water users and conducting a survey of this sample for an estimate of groundwater use.

From PTTW records, the following information is required:

- permit number,
- general and specific purpose,
- maximum litres/day,
- days per year of taking,
- identify a sub-sample of largest water users by volume, and
- conduct survey of large permitted water users for estimate of actual water use.

At a minimum, the survey should request the following information:

- raw water flow total (by month),
- raw water average daily flow (by month),
- maximum daily flow (actual), and
- consumptive use (especially relevant for industrial users – should be recorded as % of total flow or measured monthly volume consumed).

Self-Supply Water Users (Livestock) – Livestock watering may not be covered in the PTTW database. In order to appropriately estimate water usage, agricultural census data should be used in order to identify the numbers of animals by class. Each class is multiplied by a class water usage (e.g., litres/cow/day). The following information is required: numbers of livestock by class and total raw water flow (year).

Private Individual Wells – The *MOE Water Well Information System (WWIS)* will provide well records for users in the study area watershed, including those that are not serviced by public supply systems, and uses which do not require Permits to Take Water. The WWIS reports multiple uses as first use, second use, third use, etc.. This information may be used as a guide. In some cases, knowledge of hectarage, number of residents, or livestock counts may be helpful for the larger well users. An estimate of private users should be further refined by estimating municipal populations not serviced by a public system and rural population dependent on groundwater (i.e., private wells).

An estimate of average daily flow of groundwater from private individual wells can be made by multiplying the number of private well records in the study area by 175 litres/capita/day (the coefficient for domestic per capita water use). Where information is available, estimates should be categorized by sector.

2.5 Summary of Products for the Groundwater and Aquifer Characterization Studies

The following products and associated data sets or databases should be produced for the study area, using specified data sources, methods, and rules outlined in this document and in *Schedules A to G* as attached:

I. Groundwater and Aquifer Characterization Studies

❑ **Geological Maps**

- Bedrock Geology
- Quaternary Geology
- Surface Topography
- Surface Drainage
- Ground Surface
- Bedrock Surface
- Overburden Thickness
- Sand and Gravel Thickness

❑ **Hydraulic Subsurface Maps**

- Water Table
- Potentiometric Surface
- Aquifer Flow Patterns
- Potential Recharge Areas
- Potential Discharge Areas
- Specific Capacity
- Aquifer Classification (material, confined, unconfined, and semi-confined)
- Water Chemistry

❑ **Three Dimensional Conceptual Geological Framework and Model**

- Catalogue of High Quality Boreholes
- Bibliography of Relevant Literature
- Cross-sections
- Panel Diagrams
- Golden Spike Information
- Golden Curtain Information

❑ **Groundwater Intrinsic Susceptibility (GwIS) Maps**

- Intrinsic Susceptibility Maps (Preliminary, Final Derived, and Harmonized)

II. Regional Contaminant Source Inventory

❑ Potential Contaminant Sources Map and GIS Database

III. Groundwater Use Assessment

❑ An estimate of the total population in the study area by watershed and the percentage of the total population which is serviced by groundwater

❑ An estimate of the volume of the daily groundwater availability from the various local aquifer flow systems, and the total groundwater withdrawn per day for all uses in the study area watershed. In addition, a breakdown of uses and demand by sector should also be provided (see classification system provided in this document)

❑ A detailed reporting of methods and information sources used (see relevant areas of this document).

3.0 Wellhead Protection Area Studies ...

At a local scale, one of the most important areas from a geographic perspective is the surface area and subsurface volume surrounding a water well or well-field that supplies a public water system. It is through this adjacent zone that contaminants are reasonably likely to move toward and reach the well supply. In particular, the production, storage, use, or release of biological and chemical contaminants can present potential risks to groundwater quality in these areas.

3.1 Required Products

Accordingly, an understanding of local groundwater conditions and potential sources of contamination is required. Specifically, all active municipal wells or well-fields in a study area should be investigated, and where lacking,
the following products generated for each one:

- ❏ **Wellhead Protection Area Mapping**, including:

  i) delineation of areas contributing water to each well

- ❏ **Contaminant Source Assessment**, including:

  i) inventory the locations and relative threats to well water quality from existing and historical potential <u>contaminant sources</u> in the Wellhead Protection Areas; and

  ii) assessment of potential <u>contaminant pathways</u> in the identified Wellhead Protection Areas.

3.2 Methodology for Mapping Wellhead Protection Areas (WHPAs)

A wellhead protection area (WHPA) must be delineated (mapped) separately for each municipal well and well-field in the ground water study area. The map should show the time of travel (TOT) capture zones, including attribute (descriptive) data and documentation regarding the model and assumptions used for each WHPA. The boundary for WHPAs should encompass the area at ground surface that overlies the saturated zones from which the water that is pumped from a well or a well-field originates.

The WHPA represents a surface projection of the entire three dimensional capture area for a well. Each WHPA should be sub-divided into ***well capture zones*** to distinguish among the areas of different potential risks posed to well water quality from various types of microbiological and chemical contaminants that could enter the water table and move with the groundwater flow to the well. The zones enable effective and economical management of those risks.

This variation in the risk potential throughout the WHPA results from the fact that bacteria have a limited life span and an adequate travel time from the point of entrance to the well may effectively inactivate these organisms. Similarly, over time, some chemical contaminants degrade into lower risk compounds or are adsorbed by the geological materials encountered along the flow path. On the other hand, other chemicals are stable in a groundwater setting and the risk from their presence may only be attenuated through dilution along the flow path.

At a minimum, three well capture zones should be delineated for each municipal production well or well field:

i) **<u>Zone 1</u>** : 0 to 2 year saturated travel time (TOT). Land uses in this zone need to be managed to avoid all possible risks, including those from bacteria and viruses.

ii) **<u>Zone 2</u>** : 2 to 10 year TOT. The main focus of the land use management in this zone should be to minimize risks from all chemical contaminants, however, the bacterial and viral risks may still be a concern.

iii) **<u>Zone 3</u>** : 10 to 25 year TOT / Zone of Contribution. The land use management in this zone needs to address risks from persistent and hazardous contaminants.

In addition, within Zone 1, a 50-day TOT area should be identified to recognize potential risks from day-to-day activities of the water utility itself, and other potential contaminant sources from municipal activities or infrastructure.

The size of well capture zones is influenced by the well pumping rate, aquifer porosity, and hydraulic conductivity. The size and shape of the zones are influenced by hydraulic gradient and flow direction, by dissolution features such as in karst geology, and the orientation and density of fractures or faults or both. The identified capture zones need not extend beyond aquifer flow boundaries. However, they may do so where the existing topographic features or geologic structure can funnel contaminants towards the aquifer flow zone because of the combination of a relatively impermeable geology and a surface slope which is directed towards the aquifer flow zone.

Note: Capture zones in rock aquifers often extend for many kilometres. In such situations, checking residence times by means of water chemistry and isotope analysis can help ensure that time of travel estimates are not excessive (e.g. where the water is thousands of years old, the defined zone of contribution may be overly large).

3.2.1 <u>Capture Zone Delineation Methodology</u>

Preferred Method – In the majority of cases, three-dimensional, steady-state computer models should be used to delineate capture zones. When properly set-up and calibrated, these models produce the most realistic time of travel boundaries. It is anticipated that the numerical code that will most frequently be used is MODFLOW. It is necessary to have data regarding well production rate, the aquifer's lateral extent, thickness, hydraulic conductivity, and flow gradients. Assumptions made in developing the model and the details of model sensitivity analyses must be provided in the final report. It is the only method for accurately delineating capture zones where there is a significant presence of: (1) discrete fractures, (2) anisotropy, (3) spatial variations in hydrogeologic parameters, (4) vertical movement of water and variation in total hydraulic head with depth, and (5) changes in water levels seasonally or during other time period measurements.

Exceptions to the requirement for applying three-dimensional models should only be considered where site-specific conditions suggest that any of the other methods described below are more appropriate and justified from a technical standpoint.

Analytical method – Analytical methods use equations to define groundwater flow, and require site-specific estimates of transmissivity, porosity, hydraulic gradient, hydraulic conductivity, and saturated aquifer thickness. Flow system mapping using analytical models to estimate time of travel may be sufficient for conservative estimates of capture zones. Two-dimensional wellhead delineation models, such as WHPA and WhAEM, are available free of charge from the U.S. EPA.

Note: Flow system boundaries may include both, physical boundaries (limits of the aquifer and structural features such as fault-block walls, zones of fractures zones, and topographical features), and hydrological features (rivers, canals, wetlands, and lakes). This method requires detailed mapping of the water table, on which flow lines are drawn perpendicular to the water-table elevation lines. Flow system boundaries can

also be used with TOT calculations to help ensure that the zone of contribution is not unacceptably large. However, in an aquifer with fractures, this is only appropriate if the aquifer acts like a uniform porous medium.

Uniform Flow Method – This method uses the following group of analytical expressions to delineate capture zones (*asterisk (*) means multiply*):

1) Distance to down-gradient null point:

X_L = **Q / (2 * π * K * b * i)**

2) Shape of outer streamline:

X = **- Y / tan [(2 * π * K * b *i) / Q * Y]**

Where the boundary limit (asymptotic width) of the capture zone:

Y_L = **± Q / (2 * K * b * i)**

The width of the capture zone is extended to the ultimate recharge area and can be made to conform to variability in the mapped flow direction.

3) Upgradient distance as a function of time:

X_t = **K * i * (t / n)**

<u>Where</u>:
X = distance along length of capture zone
Y = width of capture zone as a function of "X"
Q = maximum approved pumping rate of the well
K = hydraulic conductivity
b = saturated thickness of screened interval
i = hydraulic gradient
t = saturated travel times for each well capture zone
n = porosity
π = 3.14156....

These formulas can be calculated in a standard spreadsheet and this method is more flexible than standard analytical models since it can conform to variability in flow direction. The disadvantage is that this method generally does not take into account hydrological boundaries (streams, lakes, etc.) and aquifer heterogeneities, and it assumes no recharge. Also, it is limited to two-dimensional analyses of flow systems and capture zone delineation.

Calculated Fixed Radius Method – This method, also known as the "cylinder method", is easy to use and is based on simple hydrogeologic principles that require limited technical expertise. However, this method tends to overprotect down-gradient and under protect up-gradient areas because it does not account for regional gradients. Unless combined with flow system mapping, this method should not be used for unconfined aquifers or for confined aquifers with a sloping potentiometric surface. Calculated fixed radius capture zones are circular areas whose radius is determined using the formula (*asterisk(*) means multiply*):

r = square root [(Q * t) / (π * b * n)]

<u>where</u>: r = radius (distance from well) in metres
Q = maximum approved pumping rate of the well
t = saturated travel times for each well capture zone
b = saturated thickness of screened interval
n = porosity
π = 3.14156...

Note: Where an aquifer characterization study is not being undertaken, the intrinsic susceptibility to contamination of the aquifer(s) supplying water to municipal wells should be assessed to at least 500 metres beyond the limit of capture Zone 3. Intrinsic susceptibility to contamination is to be evaluated by

considering the thickness and permeability of the material above the water supply aquifer. The thickness of the overlying formation(s) is important, since any contaminants that are applied, deposited, or spilled on or near the ground surface will be less attenuated and will reach an aquifer more quickly where formations are thin. Low permeability surficial soils, composed largely of clay and silt, are generally less likely to transmit significant quantities of contaminants than high permeability soils such as sand and gravel. However, fractures or other openings in an aquitard overlying the aquifer could negate natural protection. Where bedrock is exposed at surface, the ground surface will be considered to be the top of the aquifer since the intrinsic susceptibility to contamination will be highly dependent upon the degree, inter-connectivity, and orientation of the fractures.

3.3 Methodology for WHPA Contaminant Source Assessment

An inventory of existing and historical potential contaminant sources should be conducted in each Wellhead Protection Area (WHPA). The purpose of this contaminant inventory is to identify past, present and future (proposed) activities that are current or potential threats to groundwater quality. When complete, the inventories will provide the basis for targeting pro-active management of all potential risks in WHPAs, and could identify the need to examine whether mitigation measures are required.

Schedule D contains a list of common point and non-point potential contaminant sources along with their corresponding North American Industry Classification System (NAICS) codes. Potential contaminant sources must be catalogued using this numbering system.

3.3.1 Required Contaminant Source Information

Information items to consider when conducting the CSI include:

- all known sources of contamination;
- all potential sources of contamination;
- potentially contaminated sites;
- inventory of related land uses and zoning designations;
- inventory of high risk activities within or near recharge areas;
- inventory of potential contaminant pathways**;
- existing monitoring programs;
- probability of contamination associated with specific land uses; and
- potentially affected groups or individuals.

***Note: The most common potential pathways to penetrate confining layers and migrate into the aquifer are improperly constructed, maintained, and abandoned wells; and excavations such as gravel pits, dug-out ponds, utility trenches. While abandoned wells and excavations are not actually considered contaminant sources, they are included in this inventory as they may create a conduit for contaminants to move downward from the surface or upward from deeper geologic formations. Information on all such potential pathways should be collected at the same time as the contaminant source inventory.*

3.3.2 Required Methods

At a minimum, the Wellhead Contaminant Source Assessment should be based on three sources of information:

1. **existing inventories** such as the MOE inventory of PCB storage sites, MOE inventory of hazardous waste generators, and county or municipal plan Land Use Schedules;

2. a **land use survey** to identify land use activities that can be classified according to their potential

as contamination sources using North American Industry Classification System (NAICS) codes where applicable; and

3. a **field survey** of all WHPAs, especially where existing information is sparse or contradictory, or where high-risk land use is suspected.

Review of existing inventories – The assessment of potential sources of contamination will make use of a number of existing inventories on file with the Ministry of the Environment, Ministry of Natural Resources, and the County and Municipality offices. The studies should include information from all of the following sources:

- MOE Waste Generator database;
- MOE PCB Database;
- MOE Waste Disposal Site Inventory;
- MOE Municipal Coal Gasification Plant Site Inventory;
- MOE Water Well Record Database;
- Ministry of Natural Resources Petroleum Well records;
- Technical Standards and Safety Authority inventory of Underground Storage Tanks (UST); and
- county and municipality Official Plan Land Use Schedules.

Suggested potential contaminant sources, and typical North American Industry Classification System (NAICS) codes are presented in *Schedule D: Catalogue of Suggested Potential Contaminant Sources*. NAICS coding is also available over the internet at www.naisc.com.

Land use survey – Following a review of existing inventories as outlined above, a land use survey should be conducted within all identified WHPAs. Land assessment maps should be obtained from the County or Municipality offices and used to identify land uses in the study area and potential contamination sources associated with the identified land uses and their coding. Zoning maps, land use schedules and business directories should also be utilized to assist in identifying specific potential sources of contamination. For specific land uses and activities that are associated with potential sources of contamination the inventory should identify the appropriate NAICS coding (refer to *Schedule D* and www.naisc.com. Where a location includes multiple land uses, each use should be documented.

Field survey and questionnaire – Following a review of available information, a field survey should be conducted. The survey may involve conducting visual inspections from the street through the WHPA noting any potential contamination sources seen that were not identified during the review of existing databases or during the land use review. In particular, note any old gas stations or evidence of pump islands, locations where water is ponding, long term auto or machine repair sites, and chemical storage locations. A field survey can clarify previously-examined sources of information which have yielded conflicting information; or situations where insufficient information is available for a given location.

A door-to-door survey questionnaire should also be completed for all industrial, commercial, or institutional facilities located within WHPAs. *Schedule E* contains a sample survey questionnaire. A detailed summary of survey results should be included in the final report. Submission of raw data (i.e., completed questionnaires) is not required.

4.0 Reporting Requirements and Minimum Data Standards ...

4.1 General Reporting Requirements

All funded studies will be required to submit the following to the Ministry of the Environment (MOE):

- ❑ Quarterly updates, a summary report, and a full final report, including all maps and associated data, to the specifications detailed in the specific portions of this Terms of Reference document.

- ❑ Three written copies of the summary and final reports, as well as one electronic copy in a recent version of Corel WordPerfect format or Microsoft WORD format <u>and</u> one electronic copy in Adobe Portable Document Format (PDF).

- ❑ Electronic file copies of all tabular and mapping data (i.e., database files, GIS files) must also be submitted with the final reports according to the general and specific data standards noted in this document, or where standards have not been explicitly stated**,** in the format within which they were created.

4.2 Data Standards

Upon completion of the Groundwater Studies, all data (source and derived data) including both spatial and tabular data will be submitted with the final reports in digital format conforming to the data standards summarized below. These standards represent the minimum data standards required for the Groundwater Studies. These standards are complementary to the descriptions of the methods, rules and products to be delivered under the studies. Collection of data beyond these standards must also be included in the final submission of data.

The standards have been subdivided into general and specific standards. General standards apply to all data sets whereas specific standards refer to the individual data sets. Please refer to the other appendices for description of methodologies to follow for the derivation of each of these data sets.

The use of the minimum standards will ensure that there is consistency across the various groundwater studies, the data can then be used as a baseline for future studies, and the data can be used in conjunction with other existing data for a variety of other purposes.

Data sharing agreements are mandatory to facilitate the transfer of existing digital information to study areas.

General Standards – The standards which follow apply to all data submitted as part of the groundwater studies.

- All data will be submitted digitally upon completion of the final reports.
- Each theme must have a metadata description consistent with the Land Information Ontario (LIO) Directory. The metadata record should describe the methodology used to generate the derived data and layers including gridding algorithm, source data sets used, etc..
- Each theme should include the source of the input data.
- All spatial data such as points, lines and polygons should be registered to the Land Information Ontario (formerly OBM) base at a 1:10,000 scale in Southern Ontario and a 1:20,000 in Northern Ontario.
- Spatial data must be submitted using a NAD83 datum conforming to the Canadian National Transformation.

- All spatial vector data should be submitted in an ESRI-compatible format (i.e., Arc/Info coverages or ArcView shapefiles, using universal transverse mercator (UTM) coordinates (double precision) and NAD83.
- All spatial vector data should include the spatial accuracy (refer to *Schedule F*).
- All spatial raster data should be submitted as Arc/Info coverages (GRIDS) or ASCII Grids using UTM coordinates (double precision) and NAD83.
- All tabular data should be submitted in a recognized RDBMS or comma delimited formats containing the minimum attribute information referred to in the specific data standards.
- The data sets must be documented including column titles, field type, field length, and a detailed description of what data is collected for each field. The vendor should include listings and descriptions of “lookup” tables used in collecting and entering the data.
- If the tabular data supports a spatial data set, primary keys must exist within both sets of data and be documented. Where tabular data is not associated with a spatial coverage, the file must include a UTM Zone, Northing, and Easting. The coordinate data should be in NAD83.
- Any errors or discrepancies with existing data sets should be documented and reported back to the source .

Specific Data Standards - In addition to the general standards listed above, the minimum standards that apply to the specific data sets are outlined in *Schedules F and G*. Where formal or interim standards exist, they will be utilized. Otherwise a minimum set of attributes will be required for each of the data sets as set out in *Schedules F and G*. Any errors or discrepancies should be reported back to the data supplier.

5.0 Definitions ...

The following Definitions apply throughout this document:

Aquifer means a geological formation, group of formations or part of a formation which stores and transmits a useable quantity of water. Aquifers can consist of porous material of relatively high hydraulic conductivity (sand, gravel), or fractured/karstic rock.

Aquifer Vulnerability means groundwater or an aquifer's intrinsic susceptibility to contamination, including both human and natural water quality impacts. Intrinsic susceptibility, in its simplest form, is a measure of the natural protection of an aquifer and to some degree surface water resulting from overlying layers with low permeability.

Capture Zone means an area surrounding a pumping well that will supply groundwater to the well within a specified period of time. Zone of Contribution means the entire area within which the water that is pumped from a well originates.

Saturated Time of Travel means groundwater travel time in the saturated zone that is needed to travel a specific horizontal distance. It does not include vertical infiltration through the unsaturated zone.

Surface Water means water bodies (lakes, wetlands, ponds - including dug-outs), water courses (rivers, streams), infiltration trenches and areas of temporary precipitation ponding.

Well Field means a clustering of two or more groundwater production wells which supply water to communal distribution system(s). The wells must be sited on a single property or directly adjacent properties and can be installed within a single or multi-aquifer system.

Wellhead Protection Area (WHPA) means the ground surface area and subsurface volume surrounding a water well or wellfield, supplying a public water system, through which contaminants are reasonably likely to move toward and eventually reach such water well or wellfield.

Schedule A

Required Groundwater and Aquifer Characterization Components with Methodologies

Aquifer Mapping - Subsurface Geologic Information				
Information	**Data Sources**	**Method**	**Rules for methods and presentation**	**Products**
Topographic Map & Drainage Surface	MNR DEM & base mapping - 1:10,000 & 1:20,000 Relevant surface water, water well and borehole point data	Use 5 km buffer zone for the designated study area Use NAD 83 Digital Elevation Model Complete local hydrologic conditioning of provincial DEM for deriving water table elevations	This means that the base DEM has been conditioned using stream data (particularly flow direction, baseflow, water temperature data and known springs). This conditioning allows the stream, lake, wetland, and other water feature data to take priority over point or contour data during the generation of the DEM and any elevation data points which conflict with descent of each drainage system are ignored.	Topographic, drainage surface and hydrologically conditioned DEM
Bedrock Geology	MNDM map at 1:1,000,000 scale		Use the MNDM legend, and appropriate stratigraphic legend	Bedrock Geology Map with MNDM legend showing borehole data
Quaternary Geology	MNDM will provide 1:50,000 quaternary maps	MNDM creates a seamless quaternary map	Use the MNDM master provincial legend	Quaternary Geology Map with MNDM legend showing borehole data
Borehole Geologic Logs	Water Well Information System MNDM geophysical cores MTO boreholes Geological Survey of Canada geophysical cores petroleum well information from MNR – Petroleum Resources Section Geophysical data- downhole geophysics logs, seismic profiles landfill borehole information from MOE MNDM open files and field notes associated with the maps hydro transmission line data municipal projects boreholes	Compare ground surface (MNR DEM) with MOE estimated ground surface Standardize geological descriptions from water well records using GSC geomaterials protocol (see Schedule B) Apply stratigraphic principles to develop conceptual geological framework When sand & gravel at surface, default to OGS definition	• Remove wells with greater than 10m difference with OBM • Use screened water wells - remove from analysis all wells with UTM or elevation reliability code more than 6 • Screen out wells with no elevation • Screen out wells with no location - (unless excellent source then field check)	Standard geomaterial data set for the study area High quality subsurface point data

Information	Data Sources	Method	Rules for methods and presentation	Products
Bedrock Surface	• water well records from MOE • bedrock topography maps MNDM	Use these in developing the bedrock surface, do kriging or contouring of wells to bedrock, or use inverse distance, with software	Show wells used for contouring on the map. as well as fault, fracture and karstic areas. Show quarries and mines.	Bedrock surface map with fault, fracture and karstic areas. Record of paleodrainage.
Overburden thickness	• bedrock surface • ground surface	Subtract contoured bedrock surface from contoured ground surface	Show streams running on rock and gravel pits.	Map of overburden thickness (isopach)
Sand & Gravel Thickness	• water well records • petroleum wells • ARIP maps	Sum sand and/or gravel from the water well record: Create isopach in 5 metres vertical intervals for a scale of 1:50,000.	5 metres continuous thickness to be used for indication of aquifers	Preliminary indication of aquifer presence and isopach thicknesses.
Aquifer Mapping - Hydraulic Subsurface				
Water Table	DEM water well records monitored wells lake and river (baseflow streams) fabric baseflow data and known springs stream monitoring	• Select well data representing the water table. • Do histograms and variance testing on the data, • Krig water table elevation surface. • Correct water table elevation surface to groundwater surface when above ground. • Calculate depth to water table surface by subtracting water table elevation from ground surface. and use DEM Where appropriate: - tie to monitored data	Choose appropriate shallow wells. Use histograms, variance testing and statistical analysis where appropriate for water levels, associated aquifer and well depths (min. and max.). Use in preparing GwIS maps (refer to Section 2.0)	Water table point data for cross-sections Water Table Surface

Information	Data Sources	Method	Rules for methods and presentation	Products
Potentiometric Surface - Direction of Flow	DEM water well records need stratigraphic model from high-quality data for an improved map	-Create from deeper wells Do histograms and variance testing on the data, Evaluate gradients and flow direction for each of the aquifer units identified	Do histograms, variance testing and statistical analysis of water levels, associated aquifer and well depth minimum and maximum. Choose appropriate deeper wells	Potentiometric surface and direction of flow for each aquifer unit identified and discharge areas and potential linkages to surface water
Downward Vertical Gradient (Recharge)	• water table layer • potentiometric layer for each aquifer unit Use nested piezometer data where available	Water table is higher than potentiometric surface of an underlying confined layer - identify hummocky areas (closed drainage system) as potential recharge - consider karstic effects		Map and cross-sections showing potential recharge and discharge areas and potential linkages to surface water
Upward Vertical Gradient (Discharge)	• water table layer • potentiometric layer • baseflow surveys • (see Hinton, 1996) Use nested piezometers where available	Water table may be at a lower elevation than potentiometric surface of an underlying confined layer	Show flowing wells	Map of discharge and discharge areas and potential linkages to surface water
Potential Discharge Areas	• interpolated water table • ground surface • MNR wetlands, CAs • Temperature data – CAs • Aquatic Resource Areas – MNR • Spawning areas - MNR	Plot areas where water table is higher than ground surface elevation Includes areas adjacent to streams where baseflow, geomorphology and indicators present	Show springs	Map of potential discharge and discharge areas and potential linkages to surface water

Information	Data Sources	Method	Rules for methods and presentation	Products
Specific Capacity Maps	Water well, irrigation wells and pump tests including municipal wells, waste sites monitoring wells and permitted wells under PTTW	Pumping rate by draw down Correct for well losses, partial penetration, and mutual interference	Undertake pumping test to refine maps if pump test information is not recent Steady state and transient conditions should be defined	Compilation of high quality point data set. Maps of municipal wells with specific capacity noted
Development of Geological Model - Other Required Items				
Water Divides	Streams – drainage map Faults – structural geology Pumping test data	Pump Tests - identify recharge boundaries	Topographic map has the water divide on it	DEM with surface water divide Subsurface flow divides
Cross Sections, Panel Diagrams	Water well records Petroleum records Geotechnical logs	Develop a 3D geological model, draw cross sections based on classification system of materials Minimum of 2 cross sections Where variability of the material and the complexity of the geology is difficult to interpret this should be indicated in the presentation notes or legends Identify significant data gaps.	Cross sections must be interpreted and documented Use Sharpe et al for classification of materials Cross sections must be oriented parallel and perpendicular to groundwater flow directions and include all surface water and drainage features where appropriate	Compilation of high quality point and continuous subsurface data set. Conceptual geomaterials framework for further development of the stratigraphic model and associated groundwater occurrence & migration
Golden Spikes (High quality geophysical and stratigraphic boreholes.)	Geotechnical logs with geophysical info	Contact OGS/GSC for existing sites or drill golden spikes (critical geological cores) to develop the stratigraphic model applying the International Stratigraphic Guide 1994, Geological Society of America	Contact Regional staff, OGS and GSC to determine best location of drilling site and follow standard GSC method for logging information	Compilation of high quality point data set.

Information	Data Sources	Method	Rules for methods and presentation	Products
Golden Curtains (High quality seismic data)	Several golden spikes and seismic information will form a golden curtain	Use existing and new golden spikes to develop the stratigraphic model applying the International Stratigraphic Guide 1994, Geological Society of America		Compilation of high quality continuous subsurface data set.
Groundwater and Aquifer Intrinsic Susceptibility				
Areas sensitive to groundwater contamination	• water well records and boreholes • GSC Geomaterials Protocol • K-Values and K-Factors from Schedule C • Groundwater Intrinsic Susceptibility Index (ISI)values are calculated for intrinsic susceptibility for each borehole/well location	general outline: Intrinsic Susceptibility to Contamination • score is derived by adding index values calculated for each hydrogeological unit for a defined effective thickness (i.e., water table, first aquifer, 15m, etc.) • index value calculated by multiplying the thickness of each unit and a representative K-Factor • K-Factor is assigned to K-Values generally representative of the exponent of saturated vertical hydraulic conductivity of the unit when expressed in m/s	*A* - Determine and sum depth of units to water table, effective thickness, or 15m. *B* - Calculate ISI values - Use borehole data - Apply GSC Geomaterial Protocol from Schedule B - Apply The Generic Representative Permeability (K- Factor) Table from Schedule C -show ISI values on maps *C* - Use thresholds in Section 2.2.4: Categorizing ISI Values	Preliminary, final derived, and harmonized maps of intrinsically susceptible areas – high, medium and low Corresponding data sets

Schedule B

GSC Geomaterial Protocol

There is a need to standardize the descriptions of subsurface material as reported in water well and other borehole data. We recommend that the Geological Survey of Canada (GSC) Geomaterial Protocol be used to help build improved muncipal hydrogeological data sets for further analysis and interpretation.

The GSC Geomaterial Protocol provides the basis for a standardized approach to material descriptions for all borehole information used in a groundwater study. The protocol is best applied at the outset of a project and directly to borehole data sets received from various agencies. The coding routine is best used within a relational database structure (e.g SiteFx software). Use of a relational database facilitates the standardizing of a large number of boreholes and information such as the 212 fields in the MOE water well records.

The coding protocol was developed by geologists who re-coded material descriptions found in provincial water well records. The records allow for the use of three fields for drillers to enter material descriptions; however, only one field was used in most records. To partly compensate for this problem, the geologists linked re-coding rules to the many thousands of field sites they observed during geological mapping studies. In 1998, the GSC published the results of their extensive testing program as part of database developed through the Oak Ridges Moraine Hydrogeology Project. One conclusion of the re-coding and field testing was that the “clay” descriptions are over represented compared to their occurrence in the field, by a factor of 10. This is a significant finding because “clay” material is often used as a key factor in determining groundwater vulnerability.

A description of the geomaterial protocol to be used in municipal groundwater studies funded by the province is found in the following reference:

Standardization and assessment of geological descriptions from water well records: Greater Toronto and Oak Ridges Moraine Areas, southern Ontario, Russell, H. A. J., Brennand, T. A., Logan, C., and Sharpe, D. R., 1998, Current Research 1998-E: Ottawa, Geological Survey of Canada, p. 89-102.

The Ontario Ministries of the Environment, Natural Resources, Mines and Northern Development contribution have been acknowledged in the reference. The reference is available through the internet site at: http://sts.gsc.nrcan.gc.ca/orm/acrobat_data.asp.

The abstract and tables 1, 3 4. and 5 are presented here, followed by the suggested method for documenting the Metadata for the GSC Geomaterial Protocol.

Abstract

Archival drilling records from water wells, geotechnical, mineral exploration, and hydrogeologic studies provide subsurface information for regional geologic and hydrogeologic investigations. This paper evaluates methods by which water well material descriptions may be standardized. In Ontario, material descriptions are reported in three attribute fields using 82 terms, thus theoretically permitting over 500,000 permutations. Materials descriptions are rationalized to 10 classes then reclassified according to two methods: (i) First-Attribute Method (FAM), and (ii) Rule-Based Method (RBM). The first-attribute method is presently applied by hydrogeologists in southern Ontario and uses only the first attribute field; it is a simple, effective method able to broadly delimit aquifers and non-aquifers. The rule-based method applies conditional rules developed from regional geologic models. This method is more geologically accurate, and is recommended where water well data are to be integrated into geologic and hydrogeologic investigations. Successful applications are summarized and general recommendations made.

Schedule B (continued)

Header	Geology	Hydrogeology	
Well Number (2)	Unit - Depth to Top (24)	Piezometer Indicator (1)	Casings (18)
Municipality (2)	Unit - Colour (24)	Water - Depth Found (5)	Screens (8)
Concession – Range (4)	Unit - Materials (3x24)	Water - Kind (5)	Plugs (6)
Lot (2)		Test Method (1)	
Owner (1)		Pumping (2)	
Completion Date (3)		Levels (2)	
UTM Location (4)		Pumping/Recovery Indicator (1)	
Elevation (2)		Level During Pumping (4)	
Basin (5)		Flow Rate (1)	
Water Use (2)		Clear - Cloudy (1)	
Drill Method (1)		Recommended Setting (1)	
Data Source (1)		Recommended Rate (1)	
Contractor Code (1)		Specific Capacity (1)	
Date Received (3)		Final Status (1)	

Schedule B (continued)

Table 3 - Rationalized Descriptors for MOE WWIS. (%- usage in all 3 materials data fields)				
Rationalized Descriptor	**MOE Dataset Descriptor**			
1 bedrock (0.1%)	18	sandstone	40	flint
	20	quartzite	41	gneiss
	21	granite	42	greywacke
	22	greenstone	43	gypsum
	26	rock (bedrock)	44	iron fm.
	36	basalt	45	marble
	37	chert	46	quartz
	38	conglomerate	47	schist
	39	feldspar	48	soapstone
1.1 limestone (0.8%)	15	limestone	16	dolostone
1.2 shale (0.9%)	17	shale	82	shaly
	19	slate		
2 gravel (9.7%)	11	gravel	31	coarse gravel
	12	stones	32	pea gravel
	13	boulders	72	gravelly
	29	fine gravel	87	stoney
	30	medium gravel		
3 sand (12.3%)	7	quicksand	10	coarse sand
	8	fine sand	28	sand
	9	medium sand	81	sandy
4 silt (1.5%)	6	silt	84	silty
5 clay (16.1%)	5	clay	61	clayey
6 diamicton (0.5%)	14	hardpan	34	till
7 organic (0.1%)	3	muck	33	marl
	4	peat	35	wood frags.
8 fill (3.7%)	1	fill	25	overburden
	2	topsoil		
9 previously dug (0.7%)	0	unknown	24	previously drilled
	23	previously bored		
99 null (53.6%)	27	-		

Schedule B (continued)

Table 4: Geologic Descriptions and Usage - example : ORM		
Geologic Description		**Usage %**
99	no obvious material code	0.15
11	covered; missing; previously bored	0
10	fill (incl. topsoil, waste)	13.29
9	organic	0.15
8	clay, silty clay	21.21
7	silt, sandy silt, clayey silt	2.52
6	sand, silty sand	28.68
5	gravel, gravelly sand	14.89
4 4-1	clay-clayey silt diamicton clay-clayey silt diamicton, stoney	0.22
3 3-1 3-3	silt-sandy silt diamicton silt-sandy silt diamicton, stoney diamicton, texture unknown	13.90
2 2-1	silty sand-sand diamicton silty sand-sand diamicton, stoney	0.41
1 1-1 1-2 1-4 1-5 1-7	bedrock limestone shale dolomite potential bedrock interbedded limestone/shale	4.58

Examples of geological reclassifications based on the application of conditional rules presented in Table 5

Descriptor 1	Descriptor 2	Descriptor 3	
Bedrock			Bedrock (1)
Clay	Gravel		Silt diamicton (3)
Silt	Shale		Shale (1-2)
gravel	sand		Gravel (5)

Schedule B (continued)

General Process for Applying the GSC Geomaterials Protocols to a Borehole Database

MAIN STEPS

I. Simplify Descriptor Strings:

I.1. If organic has an accompanying descriptor, then organic is treated as null (see I.5).
I.2. If clay occurs with sand or gravel, then clay is treated as silt.
I.3. If bedrock descriptor is not for the last unit of the well or not with continuous bedrock beneath, then bedrock is treated as gravel.
I.4. If clay or silt is with shale, then clay and/or silt is treated as null (see I.5).
I.5. Remove duplicate attributes and spaces; eliminate all leading null fields.

II. Apply Global Rules

II.1. If a single descriptor, then the description is based directly on that descriptor (see Table 4).
II.2. If till in any field, then treat as diamicton (see Subroutine A below).
II.3. If gravel is in any field with no bedrock and clay is not first descriptor, then treat as gravel.
II.4. If fill and previously dug in any field are without bedrock, then treat as fill; else with bedrock, then treat as potential bedrock.
II.5. If all fields are null, then treat as no obvious material code.
II.6. If previously dug or fill are in any field except with bedrock, then treat as fill.

III. Apply Bedrock Rules

(Apply if last unit in well or if continuous bedrock beneath)

III.1. < 5 m depth, bedrock anywhere then code = bedrock (see Subroutine B below for categories)
III.2. > 5 m depth, bedrock anywhere and gravel anywhere then code = gravel
III.3. > 5 m depth, bedrock anywhere and sand/silt/clay and no gravel then code = diamicton (see Subroutine A below)

IV. Apply Sediment Texture Rules

IV.1. Attribute 1 = sand with attribute 2/3 = silt or clay and no gravel, then treat as sand
IV.2 Attribute 1 = silt with attribute 2/3 = sand or clay and no gravel, then treat as silt
IV.3 Attribute 1 = clay with attribute 2/3 = sand or silt and no gravel, then treat as silt

SUBROUTINES

Subroutine A: Determine Diamicton Texture

(Use textural sand-silt-clay attribute in highest attribute position)

1. If sand, then treat as silty sand diamicton
2. If silt, then treat as silt diamciton
3. If clay, then treat as clay silt diamicton
4. If no texture indicated, then treat as silt diamicton

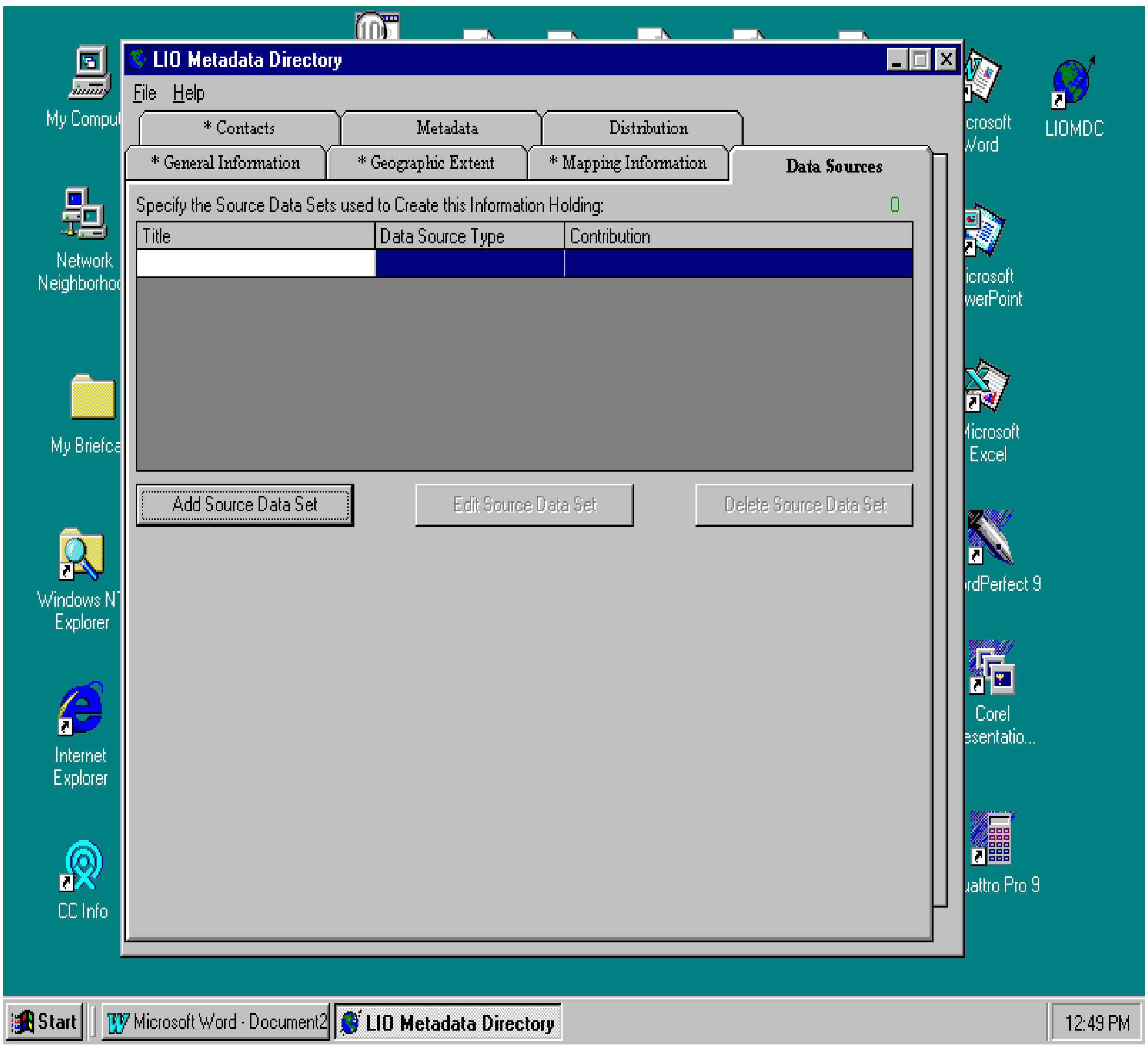
Subroutine B: Determine Bedrock Lithology

1. If bedrock in any field and not with limestone or shale, then treat as bedrock
2. If limestone in any field and not with shale, then reclassify as limestone
3. If shale in any field and not with limestone, then reclassify as shale
4. If limestone and shale in any field, then reclassify as interbedded limestone - shale

Schedule B (continued)
Metadata for the GSC Geomaterial Protocol

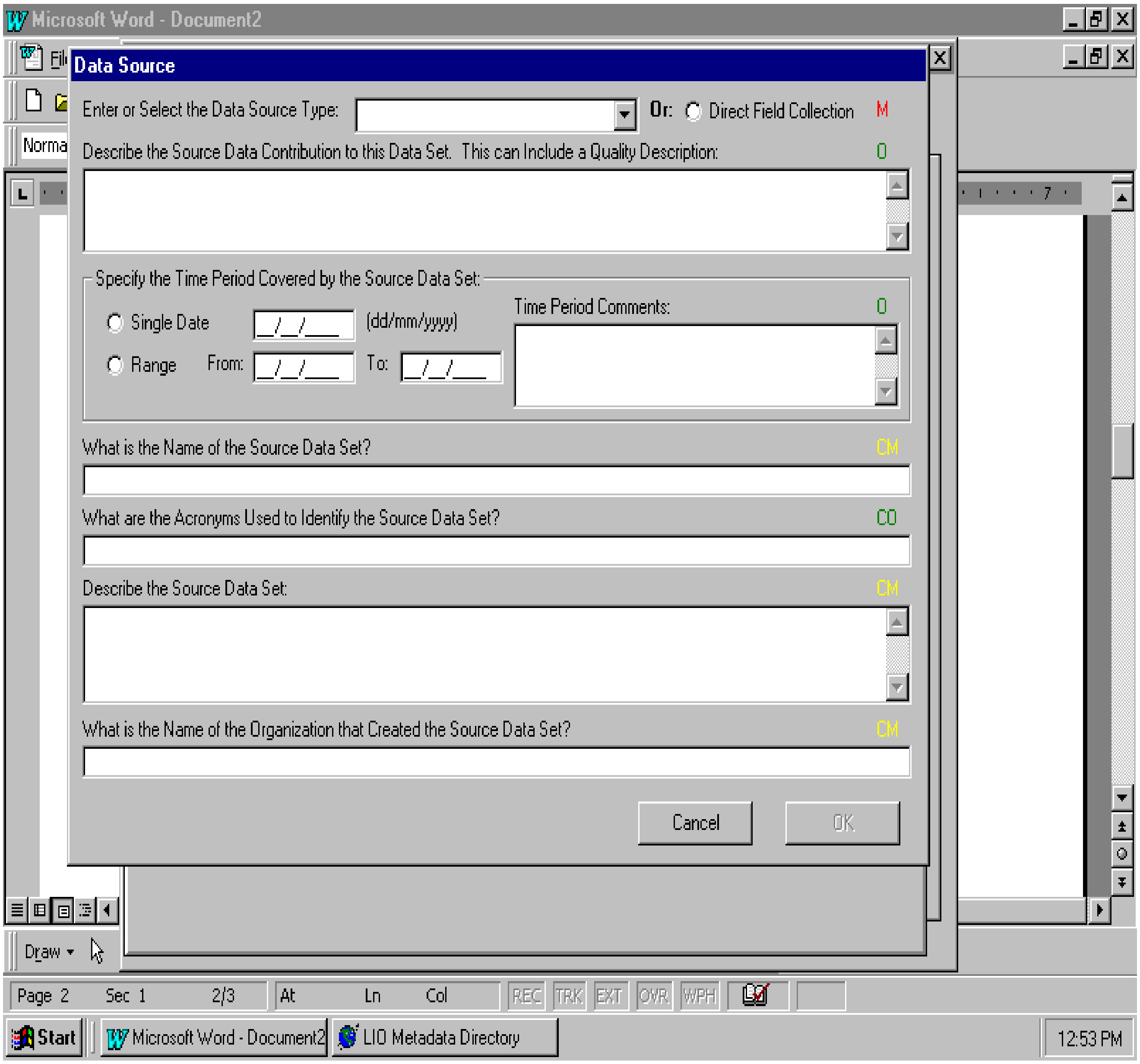
(1) As per the provincial standards, GO-ITS metadata format is used by the Ministry of the Environment to catalog the maps, tables and databases (including GIS data layers) coming out of the studies for the LIO data directory (see web site www.lio.mnr.gov.on.ca).

(2) The “Data Sources” field (which is an optional field, as it currently stands) can be used to cite the GSC Geomaterial protocol, which should be used to simplify the MOE water well records describing borehole material. This would be an essential step in producing data layers such as Aquifer Distribution & Thickness, Overburden Thickness, Bedrock Topography, Aquifer ISI, Aquifer Recharge Area (Surficial Sands & Gravel) etc. A screen shot of the “Data Sources” field is given below.



Schedule B (continued)

(3) If you click on “Add Source Data-Set”, a detailed template as shown below will appear. Details about this protocol can be described here, including its contribution towards the creation of the specific data set to which this metadata applies. This data set can be one of the data layers described above (i.e. Aquifer Distribution & Thickness, Aquifer Intrinsic Susceptibility, etc.).



Schedule B (continued)

4. For example, to create an “Aquifer Intrinsic Susceptibility” data set, you may require (in addition to the GSC Geomaterial Protocol) the MOE Water Well Records as well as MNR Digital Elevation Model (DEM). Hence, the “Data Sources” corresponding to the Aquifer Intrinsic Susceptibility metadata descriptors would include descriptions about MOE Water Well Records, MNR-DEM and GSC Geomaterial Protocol. Listed below is the Lineage information (equivalent to “Data Sources”) pertaining to the Aquifer Intrinsic Susceptibility data set as provided in the Oxford County’s metadata descriptors (FGDC Content Standard was used prior to LIO Metadata standard application).

Lineage*:*

Source_Information:

Source_Citation:

Citation_Information:

Originator: Ontario Ministry of the Environment (comp.)

Publication_Date: Unpublished

Title: Water Well Record Database

Geospatial_Data_Presentation_Form: Tabular Digital Data

Type_of_Source_Media: Disc

Source_Time_Period_of_Content:

Time_Period_Information:

Range_of_Dates/Times:

Beginning_Date: 00001931

Ending_Date: 00121999

Source_Currentness_Reference:

Current as of October 2000 (last cut of the database prior to the generation of the AVI data). Last borehole construction date entered in the database was December 1999.

Source_Citation_Abbreviation: None

Source_Contribution:

Includes borehole records which were interpreted and used in the generation of the Aquifer Intrinsic Susceptibility Index data.

Source_Information:

Source_Citation:

Citation_Information:

Originator: Ontario Ministry of Natural Resources

Publication_Date: Unpublished

Title: Oxford County Digital Elevation Model (10 metre resolution)

Geospatial_Data_Presentation_Form: Arc/Info Grid

Type_of_Source_Media: Disc

Source_Time_Period_of_Content:

Time_Period_Information:

Single_Date/Time:

Calendar_Date: 00002000

Source_Currentness_Reference: Current until new data becomes available.

Source_Citation_Abbreviation: None

Source_Contribution:

Used to extract surface elevations at each borehole location in the Water Well database.

Schedule C

Generic Representative Permeability (K-Factor) Table

Geomaterial	Representative K-Factor (dimensionless)*	K-Value (m/s) @75% range**	Highest K-Value (m/s)
gravel	1	1.00E-01	0.1
weathered dolomite/limestone		1.00E-06	
karst		1.00E-03	
permeable basalt		1.00E-03	
sand	2	0.01	1.00E-02
peat (organics)	3	1.00E-03	1.00E-03
silty sand		1.00E-04	
weathered clay (<5m below surface)		1.00E-04***	
shrinking/fractured & aggregated clay		1.00E-04***	
fractured igneous metamorphic rock		1.00E-05	
weathered shale		1.00E-05***	
Silt	4	1.00E-06	1.00E-06
loess		1.00E-06	
limestone/dolomite		1.00E-06	
weathered/fractured till	5	1.00E-07	1.00E-07
diamicton (sandy, silty)		1.00E-07***	
diamicton (silty, clayey)		1.00E-08***	
sandstone		1.00E-07	
clay till	8	1.00E-09***	1.00E-09
clay (unweathered marine)		1.00E-10	
unfractured igneous and metamorphic rock	9	1.00E-13	1.00E-13

* Representative K-Factors are relative numbers and do not correspond directly to the exponent or index of the observed K-Values for the geomaterial in the group.

** Correspondence with descriptors of observed K-Values in Freeze & Cherry 1979, Prentice-Hall. Derived using the length of the line to determine the 75% value and rounding to the highest K-Value.

*** Estimated value based on field studies in Ontario

NOTE: When actual study area data is available, this chart should be used to assign the corresponding K-Values for locally defined geomaterial (e.g., Mayhill Till) and then apply the appropriate Representative K-Factor in the calculation of the index of the groundwater intrinsic susceptibility to contamination .

Schedule D
Catalogue of Suggested Potential Contaminant Sources

Number	Decription	Typical NAICS* Codes
1	**Agricultural pesticide, herbicide, and fertilizer storage, use, filling, and mixing areas**	115000, 422910, 325320
2	**Airport maintenance and fueling sites**	488119
3	**Animal watering troughs located near unfenced wells and springs that attract livestock**	112990
4	**Beauty salons**	812112
5	**Boat builders and refinishers**	336612
6	**Chemical reclamation facilities**	562910, 324191
7	**Concrete, asphalt, tar, and coal companies**	327331, 325520,
8	**Dry cleaners and laundromats**	812300
9	**Exfiltration lagoons**	562219
10	**Feed lots and animal feeding operations with more than ten animal units**	112112
11	**Food processors, meat packers, and slaughter houses**	31160, 422470
12	**Fuel, oil and heating oil distributors and storage sites (above ground and underground storage tanks - residential, commercial and retail)**	422710, 213112
13	**Funeral homes, mortuaries, cemeteries (grave yards)**	812210, 812220
14	**Furniture strippers, painters, finishers, and appliance repairers**	81142
15	**Golf courses, parks, and nurseries**	71391, 71219o, 942120
16	**Industrial manufacturers: chemicals, pesticides, herbicides, paper/leather products, textiles, rubber, plastic, fiberglass, silicone, glass, pharmaceutical, and electrical equipment, etc.**	233310, 233310, 31-330000
17	**Junk and salvage yards, wreckers**	333923
18	**Land application of manure, sewage sludges, fertilizers, pesticides**	562212, 112112
19	**Machine shops, metal platers, heat treaters, smelters, annealers, and descalers**	332710
20	**Manure piles**	112112
21	**Medical, dental, and veterinarian offices**	621111, 621210, 541940
22	**Mining operations (including tailings and waste rock piles)**	212399
23	**Municipal wastewater treatment plants**	22131022132
24	**Pesticide and herbicide storers and retailers**	422910

Number	Decription	Typical NAICS* Codes
25	**Pipelines**	486110
c26	**Photo processors and print shops**	323114, 325992
27	**Railroad yards**	488210
28	**Research laboratories**	541710, 325412, 62151,
29	**Residential pesticide, herbicide, and fertilizer storage, use, filling, and mixing areas**	5.61730422910e+17
30	**Road salt and sand-salt storage facilities and areas where road salt is applied**	488490, 212393, 560000
31	**Sand and gravel mining operations**	212321
32	**Sewer lines**	221320
33	**Septic tank/drain-field systems**	22132
34	**Sites of reported spills**	562910
35	**Smelting and refining of non-ferrous and precious metals**	331400, 331500, 333511, 31-330000
36	**Snow dumps**	561730
37	**Stormwater impoundments, dug-out ponds**	221310, 234990, 562998
38	**Transportation corridors on which spills could occur or road salt applied**	484230, 484220, 488490, 48-490000
39	**Vehicle body shops, dealerships, maintenance garages, small engine repair shops, muffler shops, quick lubes, service stations, rental companies, rust proofers, tire shops, and car/truck washes**	811121, 441110, 811111, 811411, 811112, 81198, 811192
40	**Waste disposal sites (private, municipal, industrial), waste transfer stations, industrial waste storage areas, waste injection wells, landfills, dumps**	562219, 562212, 562112
41	**Wells (Active and abandoned)**	213000, 221310, 422490
42	**Wood preservers**	321114
43	**Other potential contaminant source (chemical)**	31-33000, 325411, 422690
44	**Other potential contaminant source (biological)**	110000, 325320, 541380, 621511, 422210, 324412, 325132

*NAISC - See www.naics.com for more information and detailed codes. The appropriate code can be searched for by code number or activity description and an appropriate code shall be selected on the basis of a land use and/or potential contaminant source inventory. See *Schedule E* for further details regarding contaminant source inventory.

Schedule E

Sample Contaminant Survey/Questionnaire

(Insert name of study region here)

Groundwater Study **Date:**____________________

Business/Chemical Use Inventory **Please fax to (phone #) by:**____________________

1. Facility Information

Facility Name:______________________________ ❑ Completed at time of visit

Street Address:______________________________ ❑ Left for business to complete

Georeferenced Location: Latitude:__________ Longitude:__________ ❑ Not completed

Person Interviewed:______________________________

Title:______________________ Phone:____________________

Name for the Mailing:____________________ Title:______________

Mailing Address:______________________________

City:________________ Prov:______ Postal Code:________

Did you know your facility is located close to a municipal well? ❑ Yes ❑ No

If known, please indicate any previous facilities on the

2. Type of Service/Product

NAICS code: __________

(refer to Terms of Reference, *Schedule D*)

Facility Type:

❑ Office	❑ Restaurant	❑ Medical	❑ Agriculture: Livestock Operations
❑ Gas Station	❑ Industry	❑ Dry Cleaner	❑ Agriculture: Crops/Nursery
❑ Computers	❑ Waste Management	❑ Automotive	❑ Printer/Photo Processor
❑ Manufacturing	❑ Other____________________		

3. Materials Handling

How do you dispose of waste?	❑ On site	❑ Off site	
Is spill cleanup equipment available?	❑ Yes	❑ No	
Is there a septic system on site?	❑ Yes	❑ No	❑ Unknown
Are there floor drains in the shop?	❑ Yes	❑ No	❑ Unknown

Any wells on site?	Industrial Use Well	❑	Number of Wells:______
	Abandoned/Unused Well	❑	Number of Wells:______
	Irrigation Well	❑	Number of Wells:______
	Drainage Well	❑	Number of Wells:______
	Drinking Water Well	❑	Number of Wells:______
	Observation Well	❑	Number of Wells:______

Is there an Environmental Mgt System in Place? ❑ Yes ❑ No Date Initiated__________

Microbiological Contaminants Storage

	Estimated Volume	Type of Storage Container: Earthen	Concrete	Metal	Physical State (Sol/Liq/Gas)
Biosolids (e.g., pulp/paper waste)	________	❑	❑	❑	________
Septage	________	❑	❑	❑	________
Sewage Sludge	________	❑	❑	❑	________
Agricultural Manure	________	❑	❑	❑	________
Other Animal Waste	________	❑	❑	❑	________

Organic Contaminants Storage

Liquid Solid	<25L (<5 gal) <25Kg	25-250L (5-50 gal) 25-250Kg	250-2500L (50-500 gal) 250-2500Kg	>2500L (>500 gal) >2500Kg	Above Ground Tank	Below Ground Tank	Physical State (Sol/Liq/Gas)
Petroleum Products	❑	❑	❑	❑	❑	❑	________
Insecticides/ Herbicides	❑	❑	❑	❑	❑	❑	________
Brake/Transmission Fluid	❑	❑	❑	❑	❑	❑	________
Acids/Bases/Caustics	❑	❑	❑	❑	❑	❑	________
Paints/Dyes/Stains	❑	❑	❑	❑	❑	❑	________
Cleaning Solutions (soap, detergents, etc.)	❑	❑	❑	❑	❑	❑	________
Chlorinated Solvents (degreasers, dry cleaning fluid, TCE, etc.)	❑	❑	❑	❑	❑	❑	________
Other Solvents (MEK, MIBK, acetone, varsol, etc.)	❑	❑	❑	❑	❑	❑	________
Film Chemicals	❑	❑	❑	❑	❑	❑	________
Registered Wastes (PCBs, asbestos, etc.)	❑	❑	❑	❑	❑	❑	________

Inorganic Contaminants Storage

	Estimated Volume	Physical State (Sol/Liq/Gas)
Fertilizers	________	________
Salt	________	________
Other______________	________	________

5. Landscape Application of Materials

	Yes	No	Estimated Area of Application
Nutrients (manure, biosolids)	❑	❑	____________________
Fertilizers	❑	❑	____________________
Pesticides	❑	❑	____________________
Salt (e.g., paved surfaces)	❑	❑	____________________
Other ________________	❑	❑	____________________

Comments:____

Schedule F

Required Data Standards

In addition to the general standards listed elsewhere in the Technical Terms of Reference, the following minimum standards apply to the specific data sets. Where formal or interim standards exist, they will be utilized. Otherwise a minimum set of attributes will be required for each of the data sets below.

Any errors or discrepancies should be reported back to the data supplier.

Table 1: Specific Data Standards

Information	Data Standards	Minimum Attributes	
Topographic Map & Drainage Surface	Existing LIO standards (1:10000 & 1:20000) *www.lio.mnr.gov.on.ca	As per existing standards	Vector
Bedrock Geology	Existing LIO standards (Bedrock at 1 million) *www.gov.on.ca.mndm/mines	As per existing standards	Vector - polygon or line
Quaternary Geology	Existing LIO standards (Quaternary Geology OGS for 1:50 000 *www.gov.on.ca.mndm/mines	As per existing standards	Vector - polygon or line
Ground Surface	Existing MNR DEM standards	Elevation - in metres above sea level	Raster
Bore holes to use if available	New boreholes drilled in the groundwater studies must have a water well record Submitted data must conform to water well information system and SiteFX standards for additional information (such as geotechnical info) also use new petroleum resource water data *www.earthfx.com	Refer to water well information system or SiteFX documentation	Vector - Points Wells utilized in analysis must be identified for each derived data layer and included in documentation
		Bedrock elevation - in metres above sea level of the bedrock Fault Line	Raster surface with faults identified as vectors (lines)

Information	Data Standards	Minimum Attributes	
Overburden Thickness		Depth in metres	Raster
Sand & Gravel Thickness	OGS/GSC standards GSC Geomaterial Protocol see Schedule B *www.sts.nrcan.ca:80	Depth in metres Type of material (e.g. sand, gravel)	Raster
Water Table		Depth to water table in metres	Raster
Potentiometric Surface- Direction of Flow		Potentiometric gradient - Flow direction	Raster - gradient Vector - flow
Downward Vertical Gradient (Recharge)		Potentiometric gradient	Raster
Upward Vertical Gradient (Discharge)		Potentiometric gradient	Raster
Potential Discharge Areas		Potential discharge area	Raster
Water Divide		Water divide - streams - geological faults	Vector - line
Golden Spikes/ Curtains	Refer to OGS/GSC standards		Vector - points - lines
Area Sensitivity to Contamination	Refer to Section 2- methodology for K-Values, K-Factors and GSC Geomaterial Protocol Schedule B	Index - actual index value Index class - low, medium or high	Raster
	Refer to Section 3.0	Zones	Vector - polygons

Information	Data Standards	Minimum Attributes	
Regional/WHPA Potential Contaminant Sources	Refer to schedule for list of potential contaminant sources North American Industry Classification System NAICS codes www.naics.com	Potential contaminant source type Activity type	Vector - points, polygons
Regional/WHPA Land Use	North American Industry Classification System NAICS codes *www.naics.com	Land Use type Activity type	Vector - polygons
Well Integrity Assessment	MOE WWIS	Location, construction date, elevation, flooding potential, casing depth/height above ground, well depth, depth to water producing zones, screened interval	Vector - points
Water Wells	Refer to SiteFx standards *www.earthfx.com	Specific Capacity Pump Test etc.	Vector - points
Pathways Inventory		Pathway type	Vector - points, lines, polygons
Groundwater Use	Required data fields: well name being pumped, well name monitored, date, time, reading of water depth, water level units (metres) Formatted as a date/time field.		Table form
	Land Information Ontario Metadata Standards *www.lio.mnr.gov.on.ca *www.gov.on.ca/mbs/techstan/72-00.htm	Data sources, processes, etc.	database/ directory

* suggested web sites

Other web references and contacts:

http://gsc.nrcan.gc.ca/esv/canadasurficial/cansurf.htm (Geology - federal)

http://sts.gsc.nrcan.gc.ca (Geographic names)

Scott Christilaw- 705-755-1870 - Ontario WRIP Water Resources Information Project

Cathy Owen or Terry Carter - 519-873-4642 - Ontario Petroleum Resource - Water Records Database

Frank Kenny - 705-755-2155 - Ontario Digital Elevation Model

Cam Baker, Ross Kelly, or Peter Barnett - OGS - Ontario geology

Schedule G

Base Themes from OLIW* Map Browser

Name of Theme	
Geographic Township	Geographic Township
Concession	Concession
Lot	Lot
Transmission Line	Utility Line
Pipeline	Utility Line
Rail Line	Railway
Rail Line Abandoned	Railway
Water Tank	Tank
Petroleum Tank	Tank
Pit	Pit or Quarry
Pile	Pit or Quarry
Lock	Water Structure
Airport	Airport
Tower	Tower
Contour	Contour
Lake/River	Waterbody Segment
Stream	Waterbody Segment
Road	Road Segment
Road Edge	Transport Line
Tertiary Road	Road Segment
Utility Line	Utility Line
Railway	Railway
MNR Area	MNR Area
Settlement	Settlement at 100K
Waterbody Name	Waterbody Segment

*OLIW - Ontario Land Information Warehouse. See www.lio.mnr.gov.on.ca